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Growth and Survival of Young-of-the-Year Emerald Shiners ('Notropis atherinoides') at Different Temperatures

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16. ABSTRACT

Young-of-the-year emerald shiners (Notropis atherinoides) were exposed to mean constant temperatures of 6.9, 11.9, 16.0, 19.8, 24.0, 26.9, 28.9, 31.0, 32.8, 34.9, and 36.7 C for 6 wk. Maximum rates of growth and net biomass gain occurred at 28.9 C, but these rates were not statistically greater ($P > 0.05$) than those at 26.9 and 24.0 C. Death rates were low at test temperatures up to 32.8 C but high at 34.9 C and above. The upper incipient 7-day TL50 was estimated to be 35.2. The 1-day TL50 of fish taken from the natural habitat, where peak daily temperatures ranged between 20 and 25 C during the preceding few days, was 32.6 C. Natural production of this important forage species would probably be best where temperatures are at least 19 C but not above 29 C for extended periods.

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Temperature		06S
Fishes		
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Growth and Survival of Young-Of-The-Year Emerald Shiners (*Notropis atherinoides*) at Different Temperatures

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Les auteurs ont exposé des jeunes ménés émeraude (*Notropis atherinoides*) de l'année aux températures constantes moyennes de 6.6, 11.9, 16.0, 19.8, 24.0, 26.9, 28.9, 31.0, 32.8, 34.9 et 36.7 C durant 6 semaines. Le rythme de croissance et le gain net de biomasse maximums se produisent à 28.9 C, mais ne sont pas significativement plus grands ($P > 0.05$) qu'à 26.9 et 24.0 C. La mortalité est faible à des températures d'essai allant jusqu'à 32.8 C, mais est élevée à 34.9 C et plus. On estime à 35.2 la LT50 supérieure du début des mortalités après 7 jours. La LT50 après 1 jour de poissons retirés de leur habitat naturel, avec des températures journalières de pointe allant de 20 à 25 C durant les quelques jours précédents, est de 32.6 C. La production naturelle de cet important poisson fourrage serait probablement optimale là où la température est d'au moins 19 C mais non au-delà de 29 C sur des périodes prolongées.

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THE emerald shiner (*Notropis atherinoides*) is an important forage fish in the Great Lakes and many other large inland waters (Cooper 1936; Flittner 1964; Walburg 1964; Campbell and MacCrimmon 1970). Because of its preference for large bodies of water, and the similar site preferences of industries requiring large quantities of cooling water with related heated discharges, this species is destined to encounter thermally altered habitats.

Some aspects of their thermal relations are

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TABLE 1. Responses of young-of-the-year emerald shiners (*Notropis atherinoides*) exposed 6 wk to constant temperatures while receiving unrestricted ration. Instantaneous rates are pooled means of three, 10-fish subsamples, one from each replicate for three sampling periods of 2 wk each. Weights at the start and end are means from three, 10-fish subsamples, one from each replicate.

Temperature (C) (mean and range)[a]	Wt (g)		Instantaneous rates (%/day)		
	At start	At end of 6 wk	Growth	Mortality	Net biomass gain[b]
6.9 (6.0–7.6)	0.06	0.08	0.66	0.04	0.62
11.9 (11.1–13.1)	0.06	0.09	0.83	0.12	0.71
16.0 (15.9–16.3)	0.07	0.16	1.97	0.02	1.95
19.8 (18.1–20.0)	0.12	0.41	2.92	0.01	2.91
24.0 (18.9–24.2)	0.16	0.80	3.86	0.00	3.86
26.9 (21.2–27.1)	0.19	0.95	3.80	0.00	3.80
28.9 (21.3–29.5)	0.19	1.05	4.10	0.00	4.10
31.0 (25.3–31.4)	0.24	0.84	3.00	0.00	3.00
32.8 (25.4–33.5)	0.22	0.64	2.63	0.11	2.52
34.9 (28.2–35.5)	0.20	—[c]	−0.40[d]	4.10[d]	−4.50[d]
36.7 (35.4–36.9)	0.14	—[e]	—[e]	28.66[e]	—[e]

[a]The 95% confidence limits of all reported mean temperatures is <0.1 C.
[b]Least significant difference, 95% C.L. = 0.91%/day.
[c]All fish died before 6 wk of exposure had been completed.
[d]Based on first 2 wk only. Too few fish remained for testing beyond the first sampling period.
[e]All dead within 1st wk.

already known. Spawning begins as the water reaches 20–22 C and continues through 27 C usually May through August (Gray 1942; Flittner 1964; Campbell and MacCrimmon 1970). Preferred temperatures, at summer acclimations, have been reported as high as 27 C from field observations (WAPORA 1971) and 22–25 C from laboratory studies (Campbell and MacCrimmon 1970; Barans and Tubb 1973). Barans (1972) showed that adults avoided temperatures above 27 C, and young-of-the-year above 30 C. Hart (1947) studied incipient lethal temperatures for the emerald shiner over a series of acclimation temperatures and found 30.7 C to be the highest temperature tolerated for 7 days. This study sought information about effects of temperature on the growth and survival of emerald shiners (*N. atherinoides*) during their first growing season.

Materials and Methods — The test system provided 225 ml/min of untreated Lake Superior water at constant temperatures to triplicate glass test chambers each 10 × 10 × 40.5 cm long (McCormick and Syrett 1970 unpublished data). Temperatures were monitored with a recording telethermometer calibrated once daily with a standardized mercury thermometer. The temperatures reported are the means of the daily thermometer readings except when temperature-control failed. When deviations exceeded 1 C for 1 h or more, a daily mean was calculated from the thermograph. Treatment temperatures reported are the pooled mean of three replicates. The 95% confidence limits about the reported means were all within ± 0.1 C, even though temperature-control failures permitted temperatures ranging beyond this narrow margin (Table 1). The magnitude and duration of failures were not considered sufficient to influence the results attributed to the reported treatment temperatures.

Young-of-the-year emerald shiners, approximately 15 mm long and 0.03 g in weight were collected from St. Louis Bay at the western end of Lake Superior on August 17, 1970. The water temperature was 19 C; temperatures from the same area 1 wk earlier were up to 23 C. After 13 days at 20 C the fish were transferred in a stratified random manner to their respective test chambers, 70 fish per chamber. Three extra chambers added every seventh stratum provided three, 10-fish samples for initial size determination. Over the next 18 days temperatures were adjusted from 20 C at the rate of 1 C/day to test temperatures (Table 1) to insure acclimation (Brett 1944).

Characteristics of the test water have been described by Biesinger and Christensen (1972). Dissolved oxygen concentrations during the experiment were all 5 ppm or higher with a mean saturation of 88% (68–99%). Fluorescent lamps gave a mean 12-h photoperiod normal for September–October at the Duluth, Minn. latitude, approximately 47° N.

The ration, newly hatched brine shrimp, was added in early morning, later afternoon, and during the day whenever it was noticed that most of the food was gone. On weekends fish were fed only once or twice daily.

Test chambers were cleaned daily, and dead fish were counted and removed. Subsamples of 10 fish/replicate were removed every 2 wk for weight measurements. Samples were taken in the morning before feeding so that little, if any, of the weight would be unassimilated food (Voightlander and Wissing 1974).

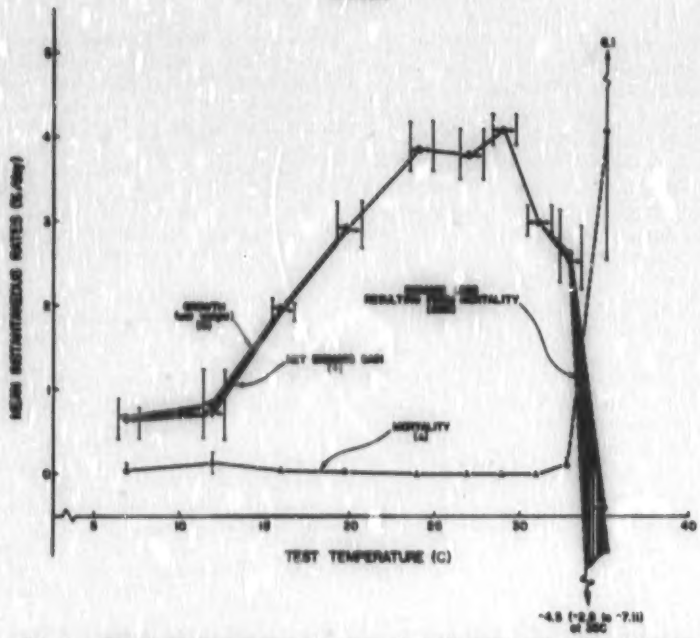

FIG. 1. Effects of temperature on mean instantaneous mortality and rates of growth and net biomass gain of young-of-the-year emerald shiners (*Notropis atherinoides*) during 6 wk of growth with excess ration. Vertical bars set to the side of the data points indicate the range of the replicate means. Dashed lines indicate data obtained from only the first 2 wk of exposure.

The sampled fish were preserved in formalin–picric–trichloroacetic solution (Davenport 1960) then later removed, blotted, and weighed intact to the nearest 0.1 mg. Ten additional fish were removed from each chamber at the end of the 2nd, 4th, and 6th wk for other experimental purposes[1] and to adjust population density as the individuals increased in size.

Instantaneous rates of mortality, growth, and net biomass gain were calculated for each sampling interval on a percentage per day basis (Ricker 1958). The rate of net biomass gain was derived by subtracting weight lost because of deaths within a test population from the rate of weight gain by survivors within the same population. Analysis of covariance was used to mathematically reduce the mean size of fish at all test temperatures to a common initial size, since size equivalency had been lost (Table 1) during the 18-day acclimation period before the start of the exposure period. The weighted mean rates for the three sampling periods were used as treatment effects in the analysis. The least significant difference (L.S.D.) derived from this calculation established the effect of temperature on the rate of net biomass gain considered significant at the 95% level. TL50 values were calculated by the method of Litchfield and Wilcoxon (1949).

Results and discussion — Mortalities were negligible, 0.00–0.12%/day, at temperatures from 6.9 to 32.8 C (Table 1, Fig. 1); no fish died from 24.0 to 31.0 C. At 34.9 C the death rate increased sharply to 4.10%/day; at 35.7 C all fish were dead within the first week. Rates of net biomass gain and rates of growth were similar at 6.9–19.8 and 32.8 C and were statistically equal at 24.0–31.0 C. The high mortality rate at 34.9 C makes this temperature as unsuitable for young emerald shiners. Mean instantaneous rates of net biomass gain were maximum (3.80–4.10%/day) at 24.0 through 29.9 C.

Growth at 31.0 C was comparable to that at 19.8 C; we suggest, however, that it may be less desirable as it lies on the too warm side of the temperature range promoting maximum growth, indicating that growth retardation is due to heat

[1] To examine the suitability of brine shrimp as a diet for fish (Bardach et al. 1972), samples of fish (27 fish after 2 wk of testing and 30 fish at test termination, 4 wk later) were analyzed by gas chromatography for total DDT analogue residues. Both groups had concentrations below 1 ppm, well within the no-known-effect level for fish. (A. W. Jarvinen, and L. H. Mueller personal communication 1974, Pesticide Study Group, National Water Quality Laboratory, Duluth, Minn.)

stress. Further evidence that temperatures of 31.0 C and higher are undesirable for young-of-the-year emerald shiners is that they avoid such temperatures (Barans 1972). The onset of teratogenic effects, such as curvatures of the spine observed in one or two fish, at 32.8 C and reduced growth rates marks this temperature as questionable for this life stage of the species. At 34.9 C teratogenic effects similar to those depicted by Tsukuda and Katayama (1957) were observed in several specimens and were accompanied by high mortality rates and slow growth resulting in negative rates of net biomass gain, clearly identifying this temperature as unsuitably high for these fish.

The 1st wk's mortality data provided an ultimate upper incipient 7-day TL50 value of 35.2 C. At 36.5 C slightly more than half the fish died in the first 3–4 days of exposure. Hart (1947) reported 30.7 C as the incipient 7-day TL50 for a mixed age-group of emerald shiners (84% age-group 0, 16% age-group I) when acclimated to 25 C. Our results show that acclimation to 25 C is not adequate to acquire tolerance to the 7-day ultimate upper incipient lethal limit which we suggest to be nearer 35 C. With fish taken directly from St. Louis Bay (ambient temperature 19 C), a 24-h TL50 value of 23.6 C was found, a result comparable to Hart's (1947) finding. The temperature history of these fish was unknown, but maximum daily temperatures on the preceding days, and thus their acclimation, was not greater than 20–25 C.

As in all growth rate studies in which an abundant to unlimited ration is used, it must be emphasized that in the wild, food is more often a limiting factor. Accordingly, maximum rates of net biomass gain would be expected to occur at progressively lower temperatures as food becomes more limiting (Brett et al. 1969).

Thus, for the well-being of young-of-the-year emerald shiners and consequently the well-being of those more frequently sought-after species that use them as food, the combined results suggest that 29 C is the maximum temperature expected to result in most rapid net biomass gain, and when food is limiting, depending on how limiting, some lower temperature would be best. During the growing season, however, temperatures below 15 C are also undesirable, and in such instances adding heat to their habitat when properly controlled may be beneficial both in extending the growing season and in stimulating daily forage production rates.

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